Feeding Lactating Dairy Cows Proteins Resistant to Ruminal Degradation[1]

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ABSTRACT

Sixty multiprious Holstein cows were fed treatment diets from 11 to 40 d postpartum with corn silage as the forage. Treatment diets each contained a different supplemental protein: 1) solvent soybean meal; 2) extruded soy product; 3) combination of corn gluten meal and distillers dried grains with solubles; and 4) a combination of protein sources from diets 2 and 3. Covariate adjusted means for milk (kg/d) and milk fat (%) for treatments 1 through 4 were 37.5, 3.14; 38.5, 3.19; 31.8, 3.45; and 35.2, 3.08. Milk protein content and DM intake were greatest for cows fed diet 1.

In a second trial, 105 multiparous Holstein cows 13 d postpartum were placed on 7 treatment diets for 60 d. Treatments 1 to 5 contained equal amounts of corn silage and alfalfa silage as forage sources and contained either: 1) solvent soybean meal; 2) roasted soybean meal; 3) roasted soybeans; 4) roasted soybeans and urea; or 5) a mixture of corn distillers dried grains and corn gluten meal. Treatments 6 and 7 had alfalfa silage as the forage source and either 6) solvent soybean meal or 7) roasted soybeans as the supplemental protein. Feeding roasted soybeans with the alfalfa silage-based diets increased milk 2.0 kg/d, 4% FCM 4.6 kg/d, and fat .23 kg/d when compared with solvent soybean meal. Milk protein production was depressed by feeding a combination of distillers dried grains and corn gluten meal when compared with feeding diets containing soybean sources with the corn silage-alfalfa silage diets. Resistant protein sources may have greater value with diets containing alfalfa silage than with diets containing corn silage.

INTRODUCTION

Milk production response to feeding of proteins that are relatively resistant to degradation in the rumen has been inconsistent. Mielke and Schingoethe (15) found no difference in milk production when soybean meal or extruded soybeans were fed, and Grummer and Clark (11) observed similar milk production with feeding soybean meal or heated soybean meal. However, in both studies, CP content of the diet was 13% and corn silage was the forage. This amount of dietary protein in combination with a resistant protein source may have resulted in inadequate ammonia in the rumen. Milk production has been increased with feeding of roasted soybeans (19) and heated soybean meal (13). Protein content of these diets was 18 and 17%, respectively.

There are several reasons for the variable milk production response to feeding of protected proteins, including stage of lactation, extent of heating of the protein source, forage fed in the diet, protein content of the diet, and protein quality or amino acid content of dietary protein. Dietary protein requirements are greatest during the first 8 wk of lactation; therefore, the greatest response to resistant proteins would be expected during this time.

Received June 1, 1987.
Accepted March 14, 1988.

[1] Trade names are used in this paper solely to provide specific information. Mention of a trade name does not constitute a warranty of the product by the US Department of Agriculture or an endorsement of the product to the exclusion of other products not mentioned.

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The length of time a protein source is heated affects its resistance to microbial breakdown in the rumen. Tagari et al. (26) found dry heating of cottonseeds caused a linear decrease of ammonia concentration as measured in vitro when temperatures increased from 120 to 180°C and as the length of heating increased from 20 to 120 min. Their work further suggests that dry heating for 20 min at 120°C may enhance protein breakdown. Temperatures above 120°C and times of 40 min or greater reduced ammonia production from that of the control. The effectiveness of heat treatment is influenced by both temperature and duration of heat exposure.

Degradation in the rumen of protein in alfalfa silage may be greater than with protein in corn silage (21). Most published work with resistant proteins has been with diets containing corn silage as the only forage. The response to resistant proteins may be different with alfalfa silage.

Distillers dried grains (DDG) and corn gluten meal (CGM) are two protein sources that are normally quite resistant to microbial degradation. Forster et al. (9) reported an increase in milk production with feeding of CGM. In contrast, Vandersall and Erdman (27) found a depression in milk production when feeding a combination of DDG and CGM. Lysine may become limiting for synthesis of milk protein when a large portion of the dietary protein is derived from corn.

The objective of this study was to determine the response in yield and composition of milk to several resistant supplemental proteins during the first 70 d of lactation. Heated soybean meal and soybeans and a combination of DDG and CGM were the resistant proteins used. Presumably, heated soy products would be good sources of lysine, and corn by-products would be good sources of methionine, the two amino acids most frequently cited as first limiting for milk production. Two forage sources were included in trial 2 because of potentially large differences in the quantity of lysine and methionine supplied by the forage component of the diet.

MATERIALS AND METHODS

Trial 1

Sixty multiparous Holstein cows were fed a high protein (18%) standardization diet during the first 10 d postpartum. On d 11 cows were randomly allotted to one of four treatments varying only in source of protein supplement. Cows were offered their treatment diets through d 40 of lactation. Diets were offered ad libitum throughout the entire experiment. Treatment milk means were obtained from d 20 to 40. An attempt was made to balance pretreatment milk averages after 40 cows had started the experiment, so the last 20 cows were not randomly assigned to experimental groups. Mean milk production during d 4 to 10 was used as a covariate to obtain adjusted treatment means. Animals developing dystocia, mastitis, or metabolic problems were replaced by the next available animal and were not used in the experiment.

Protein content of the treatment diets averaged 14.7% of the DM. Protein supplements were: 1) conventional soybean meal (SBM); 2) extruded mixture of soybean meal and whole soybeans[4] (Ext-SB); 3) a 66:34 combination of dried distillers grains with solubles:corn gluten meal (DDG-CGM); 4) and a combination of the extruded soy product, corn gluten meal, and distillers dried grains with solubles with 50% of the supplemental CP coming from the extruded soy product and 50% from the corn gluten meal:distillers dried grains with solubles (EB: CD). Ingredients and chemical composition of the diets are in Table 1. Samples of the grain mix and corn silage were taken daily and were used to make weekly composites for DM and N analysis (2). The amount of protein supplement in the diet was adjusted slightly four times during the trial to account for changes in protein content of the corn silage. Feed refusals were measured every other day and grab samples of feed refusals were composited weekly and analyzed for DM and N (2). The trial was conducted during the fall and winter and there was

[4] The extruded mixture of soybean meal and whole soybeans was supplied by Triple "F", Inc. of Des Moines, IA. This product contained, on an as-is basis, 60% of 44% CP soybean meal, 32% ground whole soybeans, 5% sodium bentonite, 1.5% lignin sulfonate, and 1.5% hemicellulose extract. The product was extruded at 149°C and held following extrusion at approximately 100°C for 90 min in insulated containers.

TABLE 1. Ingredient and chemical composition of diets (Trial 1).

	Source of supplemental protein[1]			
	SBM	Ext-SB	DDG:CGM	EB:CD
	(% dry basis)			
Ingredients				
Corn silage	56.0	56.0	56.0	56.0
Ground shelled corn	25.9	25.0	25.0	25.0
Soybean meal	15.5	...	...	...
Extruded soy product	...	16.5	...	7.9
Distillers dried grains with solubles	...	...	11.0	5.9
Corn gluten meal	...	...	5.5	2.7
Dicalcium phosphate	1.0	1.0	1.0	1.0
Limestone	1.1	1.0	1.0	1.0
Trace mineral salt[2]	.4	.4	.4	.4
Vitamin premix[3]	.1	.1	.1	.1
Chemical analysis				
Crude protein, %	14.8	14.9	14.5	14.6
NE_l, Mcal/kg[4]	1.65	1.69	1.67	1.68

[1] SBM = Soybean meal, Ext-SB = extruded soybeans and soybean meal, DDG:CGM = a 66:34 combination of distillers dried grain with solubles plus corn gluten meal, EB:CD = a combination of extruded soy product, corn gluten meal, and distillers dried grains with solubles.

[2] Composition (g/100 g); NaCl (95 to 99); Mn (>.2); Fe^{2+} (>16); Fe^{3+} (>.14); Cu (>.003); Zn (>.01); I (>.007) and Co (>.003).

[3] Composition (IU/kg): 2,000,000 of vitamins A and D; 200 of vitamin E.

[4] National Research Council tabular values.

no deterioration of orts. Corn silage, grain mix, and protein supplement were mixed daily in a Uebler mixer cart and fed as a complete mixed diet once daily.

Milk production was recorded daily. Composite milk samples from two consecutive milkings obtained once weekly were analyzed for protein and fat by infrared analysis by the Wisconsin DHIA testing lab (5301 Tokay Blvd., Madison). Cows were weighed weekly. Treatment means for milk production, milk fat, and protein production were covaried on pretreatment means. Analysis of covariance was used followed by means separation using Tukey's T-test (10).

Trial 2

One hundred five multiparous Holsteins were assigned to one of seven diets sequentially as they freshened. Cows stayed in maternity pens 3 d postcalving and then were placed on one of two pretreatment diets for 10 d. At 13 d postcalving, cows were switched to a treatment diet for 60 d. Cows allotted to the alfalfa silage-corn silage diets (mixed silage) were placed on the SBM diet with mixed silage during the pretreatment period. The alfalfa silage-SBM diet served as the pretreatment diet for cows on treatments with alfalfa silage. Approximately 2.5 kg of alfalfa hay were included in the pretreatment diets. Animals off feed for a week or longer because of metabolic problems were replaced by other animals. All diets were offered ad libitum.

Protein content of treatment diets was balanced bimonthly for 16.0% CP for the mixed silage and 18.5% CP for the alfalfa silage diets. Protein treatments for mixed silage were SBM, roasted soybean meal (Rt-SBM), roasted soybeans (Rt-SB), roasted soybeans with urea (Rt-SB-U), and a 59:41 combination of DDG-CGM. The two protein treatments for alfalfa silage were soybean meal (A-SBM) and roasted soybeans (A-Rt-SB). Treatments were established to study the effect of feeding roasted soybean sources, oil, urea, and corn by-product feeds to cows in early lactation. The percent protein was raised to 18.5% CP in the alfalfa silage diets to ensure a similar proportion of supplemental protein in all treatments. Composition of the diets is shown in Table 2. The total mixed diets were fed twice daily.

Samples of silage, high moisture ear corn (HMEC), and total mixed diets were taken daily. Feed refusals accumulated over 2 d were measured and sampled to make a weekly composite. Silage, HMEC, diets, and refusals were dried in a 60°C oven for 48 h for weekly DM determination. The weekly samples of alfalfa silage and diets and bimonthly feed refusals, corn silage, and HMEC samples were analyzed for Kjeldahl N content (2) using a copper catalyst (Kjeltabs, Tecator Inc., Herndon, VA). Acid detergent fiber (2) and NDF contents were determined on silage samples by the procedure of Robertson and Van Soest (18).

Solvent-extracted soybean meal and raw soybeans were roasted in a Gem Roaster (Winona, MN) and immediately placed, without cooling, in 227-kg barrels covered with canvas. Mean air temperature inside the roaster for soybean meal and soybeans was 205 and 420°C, respectively, and residence time of the protein supplement in the roaster was approximately 2 min. Initial and final temperatures at a depth of 30 cm in the barrels were 120 and 110°C for Rt-SB and 116 and 110°C for Rt-SBM. Following 3 h in the barrels, protein supplements were cooled and stored. Soybeans were rolled prior to storage. Protein supplements were analyzed monthly for DM and CP as de-

TABLE 2. Diet ingredients (Trial 2).

	Mixed silage[1]					Alfalfa silage[2]	
Ingredient	SBM	Rt-SBM	Rt-SB	Rt-SB-U	DDG-CGM	A-SBM	A-Rt-SB
	(% dry basis)						
Alfalfa silage[3]	27.5	27.5	27.5	27.5	27.5	55	55
Corn silage[4]	27.5	27.5	27.5	27.5	27.5	...	...
High moisture ear corn	31.5	32	28	31	31	33	30
Soybean meal	11.5	...	...	...	...	10	...
Roasted soybean meal	...	11	...	...	...	...	...
Roasted soybeans	...	...	15	12	...	...	13
Distillers dried grains	...	...	...	...	7.1	...	...
Corn gluten meal	...	...	...	...	4.9	...	...
Urea	...	...	...	.4	...	...	...
Dicalcium phosphate	.82	.82	.82	.82	.82	.82	.82
Calcium carbonate	.64	.64	.64	.64	.64	.64	.64
Trace mineral salt[5]	.43	.43	.43	.43	.43	.43	.43
Vitamin ADE[6]	.11	.11	.11	.11	.11	.11	.11
Chemical composition							
Crude protein, %	15.9	15.9	15.7	16.1	16.2	18.5	18.6
NE_l, Mcal/kg[7]	1.57	1.57	1.62	1.60	1.59	1.45	1.49

[1] Treatments with corn silage and alfalfa silage were: SBM = solvent soybean meal, Rt-SBM = roasted soybean meal, Rt-SB = roasted soybeans, Rt-SB-U = roasted soybeans with urea, DDG-CGM = 59:41 distillers dried grains with solubles and corn gluten meal.

[2] Treatments with alfalfa silage were: A-SBM = soybean meal, A-Rt-SB = roasted soybeans.

[3] Averaged 45.5% NDF and 38.5% ADF.

[4] Averaged 36.2% NDF and 22.7% ADF.

[5] Composition (g/100 g): NaCl (95 to 99); Mn (>.2); Fe^{2+} (>.16); Fe^{3+} (>.14); Cu (>.033); Zn (>.01); I (>.007); and Co (>.003).

[6] Vitamin ADE contained (IU/kg): 2,000,000 of vitamins A and D; 200 of vitamin E.

[7] Calculated from *United States-Canadian Tables of Feed Composition* (1982) assuming NE_l (Mcal/kg) for corn silage = 1.64 and alfalfa silage = 1.19.

scribed. Acid detergent insoluble N and crude fat were determined (2) on every batch of the protein supplements. In vitro degradation rates (h^{-1}) for SBM, Rt-SBM, Rt-SB, DDG, and CGM were .091, .019, .017, .019 and .004 (29).

Milk production was recorded daily. Composite milk samples were analyzed weekly for fat and protein content by infrared analysis (Wisconsin DHIA testing lab). Cows were weighed on 2 consecutive d at the beginning and end of the treatment period and once weekly during the treatment period. Days open were recorded for all cows that the herdsman decided would be bred back.

Data were analyzed by least squares using the following model:

$$y_{ijklm} = \alpha + \text{season}_i + \text{year}_j + (\text{season} \times \text{year})_{ij} + \text{parity}_k + \text{treatment}_l + (\text{treatment} \times \text{year})_{lj} + e_{ijklm}$$

where y_{ijklm} = the dependent variable for the m^{th} cow on the l^{th} treatment with the k^{th} parity in the j^{th} year and the i^{th} season, α = population mean, season_i = season of calving (calving on days of the year between: 326 to 365 and 0 to 59 = season 1, 60 to 151 = season 2, 152 to 243 = season 3, and 244 to 325 = season 4), year_j = fixed effect of the j^{th} year of calving, $(\text{season} \times \text{year})_{ij}$ = fixed effect of the i^{th} season within j^{th} year, parity_k = fixed effect of the k^{th} parity, treatment_l = effect of l^{th} treatment, $(\text{treatment} \times \text{year})_{lj}$ = the effect of l^{th} treatment within the j^{th} year, and e_{ijklm} = random error, assumed independent and identical with normal distribution.

When treatment × year was not significant in the model, it was pooled with the error term. The model was used for everything except milk production data, which included a covariate. Treatment means for milk production were covaried on milk production averaged during d 8 to 12 of the covariate peiod. Comparisons between treatments were made using the following single degree of freedom orthogonal contrasts (25): 1) mixed silage vs. alfalfa silage, 2) SBM vs. Rt-SB with alfalfa silage, 3) soybean sources (SBM, Rt-SBM, Rt-SB, Rt-SB-U) vs. DDG-CGM with mixed silage, 4) SBM vs. Rt-SBM and Rt-SB and Rt-SB-U with mixed silage. 5) Rt-SBM vs. Rt-SB and Rt-SB-U with mixed silage, and 6) Rt-SB vs. Rt-SB-U with mixed silage.

RESULTS AND DISCUSSION

Trial 1

Animal response data are in Table 3. Covaried treatment milk production was statistically lower for diet DDG-CGM than diets SBM and Ext-SB. Replacment of SBM with Ext-SB resulted in a 1.0 kg/d increase in milk production, but this difference was not significant ($P>.05$).

Cows fed diet DDG-CGM had lower ($P<.05$) DM intake than cows fed diets SBM or EB:CD. Body weight loss was greatest for cows fed diet EB:CD. These cows did not recover to their pretrial weights by the end of the experiment. Cows fed diet EB:CD had the same average dialy DM intake, expressed as a percent of body weight, as did cows fed diet Ext-SB. However, treatment EB:CD cows lost an average of 4.5 kg during the trial while those fed diet Ext-SB gained an average of .3 kg.

Milk production of cows fed DDG-CGM was markedly less than for cows receiving SBM (31.8 kg vs. 37.5 kg). Milk production of cows fed the blended protein supplement (ED:CD) was intermediate (35.2 kg). It is possible that use of the relatively resistant protein supplements in diets DDG-CGM and EB:CD resulted in insufficient degradable protein for normal growth of the rumen microbes. Reduced microbial growth due to insufficient degradable protein in the rumen could be responsible for reduced milk production with treatments DDG-CGM and EB:CD. Ruminal ammonia concentrations were measured in a companion study with ruminally cannulated cows and were found to average 7.7, 7.1, 2.6, and 4.6 m*M* for diets SBM, Ext-SB, DDG-CGM, and EB:CD. This would suggest that ammonia concentration was adequate, except for diet DDG:CGM, where it bordered on being deficient (22). Also, one cannot rule out the possibility that some other factor reduced feed intake and subsequently reduced milk production with diet DDG-CGM.

Another explanation for the relatively poor performance with the corn by-products is that these diets are particularly low in lysine. Lysine

TABLE 3. Effect of supplemental protein on milk production, milk composition, DM intake, and body weight changes (Trial 1).

	Source of supplemental protein[1]				
	SBM	Ext-SB	DDG-CGM	EB:CD	SE
Feed intake					
DM Intake, kg/d	22.5^{a}	21.3^{ab}	19.9^{b}	22.4^{a}	1.00
Daily DM intake, % of Mean body weight	3.89^{a}	3.42^{ab}	3.25^{b}	3.42^{ab}	0.155
Body weight					
Beginning body weight, kg	605^{ab}	642^{ab}	590^{b}	664^{a}	20.4
Ending body weight, kg	611^{ab}	642^{ab}	589^{b}	659^{a}	20.9
Net change in body weight, kg	+6.2	+.3	−2.0	−4.5	5.45
Pretreatment milk, kg/d	27.2	27.1	26.9	27.8	1.44
Treatment averages					
Milk, kg/d[2]	37.5^{a}	38.5^{a}	31.8^{b}	35.2^{ab}	1.64
Milk fat, %	3.14	3.19	3.45	3.08	.155
Milk fat, g/d[2]	1177^{ab}	1298^{a}	1089^{b}	1092^{b}	56.5
4% Fat-corrected milk, kg/d[2]	32.7	33.9	29.1	30.5	1.70
Milk protein, %	3.14^{a}	2.93^{b}	2.72^{c}	2.98^{ab}	.050
Milk protein, g/d[2]	1170^{a}	1128^{ab}	861^{c}	1045^{b}	30.0

^{a,b,c}Means in the same row without a common subscript differ ($P<.05$).

[1] SBM = Soybean meal, Ext-SB = Extruded soybeans and soybean meal, DDG:CGM = a 66:34 combination of distillers dried grain with solubles and corn gluten meal, EB:CD = a combination of extruded soy product, corn gluten meal, and distillers dried grains with solubles.

[2] Treatment means were covaried on pretreatment milk mean.

content of DDG-CGM diet is particularly low, since all of the dietary protein is derived from corn. Schwab et al. (24) demonstrated that lysine and methionine are likely to be the first-limiting amino acids with corn-based diets.

Milk protein content and production were higher for cows fed SBM than for those fed the Ext-SB. This is consistent with earlier trials reporting higher milk protein content for cows fed soybean meal than for those fed heat-treated soybeans (12, 19). Milk fat production was greatest for cows fed the extruded soy product, and this was higher ($P<.05$) than for cows fed diets containing the corn by-products.

The corn by-products did not support milk production as well as SBM or the Ext-SB. This reduced production may have been due to reduced microbial growth in the rumen or due to inadequate lysine supply. Milk production was slightly higher with the Ext-SB, but this difference was not significant.

Trial 2

Protein and calculated NE_l contents of the diets are in Table 2. Protein averaged 16.0% for mixed silage and 18.5% for alfalfa silage diets. The NE_l contents of the mixed silage diets were greater than the alfalfa silage diets. Compositions of the protein supplements are in Table 4.

The unadjusted means and the means across all treatments for DM intake, body weights, and milk parameters are in Table 5. There were no differences in body weight and DM intake as a percent of body weight in all contrasts tested (Table 6). Season affected DM and CP intake. Parity affected DM intake as a percent of BW.

There were no significant differences in kilograms of feed DM per kilogram milk for all contrasts tested (Table 6). However, the soybean sources fed with mixed forage tended to be more efficient than the DDG-CGM group

TABLE 4. Chemical composition of protein supplements (Trial 2).

Feed ingredient	Dry matter	Crude protein	Ether extract	ADIN[1]
	(%)	(% dry basis)		
Soybean meal	90.2	46.9	1.8	2.1
Roasted soybean meal	95.0	48.5	1.9	5.5
Roasted soybeans	95.7	37.7	22.2	4.4
Distillers dried grains-corn gluten meal	90.9	45.9	8.7	14.9

[1] Acid detergent insoluble nitrogen.

(Table 6, contrast 3). Season and parity affected all milk parameters measured except fat and protein concentration.

Cows on the alfalfa silage treatments consumed .47 kg/d more CP than did cows on mixed silage (Table 6, contrast 1). The amount of protein contained in the alfalfa diets was greater than with the mixed silage diets, so equal amounts of test protein could be fed to both forage groups. Fat-corrected milk was lower with alfalfa silage than mixed silage treatments by 1.6 kg/d. The energy content in the diets was lower in the alfalfa silage than the mixed silage treatments and may have caused the difference in milk production. Even though CP content of the diets was greater for alfalfa silage, milk protein secretion was reduced .07 kg/d. Broderick (3) also found a decrease in milk protein production with alfalfa silage vs. corn silage. The protein in alfalfa silage is readily degraded in the rumen (14). This may lead to inadequate amino acid supply for milk protein synthesis. Van Horn et al. (28) suggested that dietary protein content must be greater with alfalfa silage than with corn silage diets supplemented with soybean meal.

The greater energy content of the mixed silage diets may have contributed to the increase in milk protein as well as total milk production. Emergy (6) suggested milk protein content increases as intake of energy increases. He further stated that since added oil or fat has reduced milk protein, the extra energy must be carbohydrate or other material capable of increasing blood glucose to increase milk protein. The mixed silage diets supplied more starch in the form of corn grain than the alfalfa-based diets.

The A-Rt-SB treatment increased milk production (2.0 kg/d), FCM (4.6 kg/d), percentage fat (.36), fat production (.23 kg/d), and depressed percentage protein (.12) when compared with A-SBM (Table 6, contrast 2). The greater DM, CP, and energy intake of the A-Rt-SB treatment may have improved milk production. The increase in milk fat and depression of protein with feeding of oilseeds was consistent with the observations of Palmquist and Jenkins (17).

Milk production by periods is illustrated for alfalfa silage diets in Figure 1. Milk production was averaged over six, 10 d intervals during the 60 d treatment period. The increase in milk production with A-Rt-SB above the A-SBM diet became greater as lactation progressed. Cows

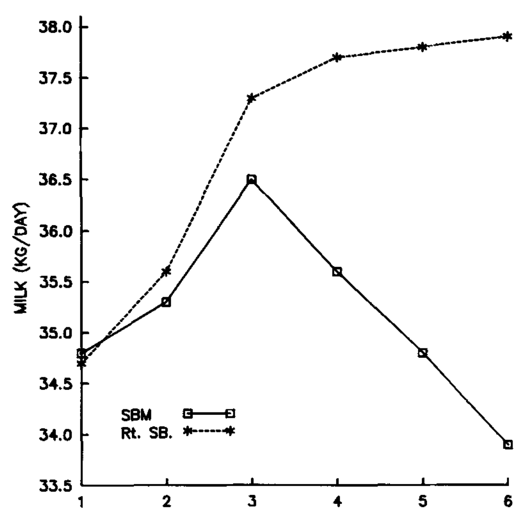

Figure 1. Adjusted means for milk production during six 10-d subperiods of the 60-d treatment period for alfalfa silage diets supplemented with soybean meal (□) or roasted soybeans (*) (Trial 2).

TABLE 5. Unadjusted means across all treatments for feed intake, body weights, and milk production (Trial 2).[1]

Item	Treatments[2]							Mean	SD
	SBM	Rt-SBM	Rt-SB	Rt-SB-U	DDG-CGM	A-SBM	A-Rt-SB		
Dry matter intake, kg/d	20.3	20.7	20.2	19.6	20.3	19.6	20.7	20.2	.45
Dry matter intake, % of BW	3.35	3.37	3.10	3.28	3.24	3.10	3.30	3.25	.10
Crude protein intake, kg/d	3.22	3.30	3.18	3.15	3.29	3.62	3.86	3.4	.09
Body weight, kg	610	620	655	605	630	640	630	627	14.7
Change in body weight, kg	−.79	−.06	−10.2	−1.5	4.09	−9.70	−11.61	−4.3	6.67
Pretreatment milk, kg/d	31.3	32.7	34.0	33.0	30.9	31.0	32.0	32.1	1.19
Milk, kg/d	37.2	38.5	38.7	37.7	35.2	35.2	37.4	37.1	.72
4% FCM, kg/d	34.5	36.1	37.0	34.5	34.2	32.3	36.4	35.0	1.02
Fat, %	3.52	3.58	3.73	3.43	3.84	3.47	3.82	3.63	.11
Fat, kg/d	1.31	1.38	1.44	.129	1.34	1.22	1.43	1.34	.05
Protein, %	2.89	2.77	2.78	2.85	2.85	2.82	2.72	2.81	.04
Protein, kg/d	1.07	1.07	1.08	1.07	1.00	1.00	1.02	1.04	.03
Feed DM/milk, kg/kg	.55	.54	.53	.52	.59	.56	.56	.55	.016

[1] Means are based on data collected from d 18 to 73 postpartum except pretreatment milk.

[2] Treatments with corn silage and alfalfa silage: SBM = solvent soybean meal, Rt-SBM = roasted soybean meal, Rt-SB = roasted soybeans, Rt-SB-U = roasted soybeans with urea, DDG-CGM = 59:41 distillers dried grains with solubles and corn gluten meal. Treatments with alfalfa silage: A-SBM = solvent soybean meal, A-Rt-SB = roasted soybeans.

TABLE 6. Orthogonal contrast.

	Parameters											
	Body weight	Δin Body weight	Dry matter	Intake	Crude protein intake	Feed/ Milk	Milk	4% FCM	Fat	Fat	Protein	Protein
	(kg/d)			(% of BW)	(kg/d)	(kg/kg)	(kg/d)		(%)	(kg/d)	(%)	(kg/d)
Orthogonal contrast 1: Mixed silage vs. alfalfa silage												
Estimated difference[1]	4.0	−4.8	−.24	−.06	.47	.02	−.91	−1.6	.03	−.06	−.06	−.07
SE	13.2	6.0	.41	.09	.08	.01	.7	.9	.10	.04	.04	.02
P	.76	.43	.56	.51	.0001	.22	.16	.08	.80	.20	.11	.004
Orthogonal contrast 2: Soybean meal vs. roasted soybeans with alfalfa silage												
Estimated difference[2]	9.2	−4.8	1.35	.16	.22	−.01	2.0	4.6	.36	.23	−.12	.03
SE	22.4	10.2	.69	.15	.13	.03	1.1	1.6	.17	.07	.06	.04
P	.68	.64	.05	.28	.09	.69	.07	.004	.05	.002	.05	.41
Orthogonal contrast 3: Soybean sources vs. distillers dried grains with solubles: corn gluten meal with mixed diets												
Estimated difference[3]	24.3	.42	−.004	−.14	.05	.03	−1.0	−.9	.19	−.009	−.01	−.06
SE	17.7	8.0	.54	.12	.10	.02	.87	1.2	.14	.58	.05	.03
P	.17	.96	.99	.23	.60	.14	.26	.47	.17	.88	.84	.07
Orthogonal contrast 4: Solvent soybean meal vs. roasted soybean meal and both roasted soybean diets with mixed diets												
Estimated difference[4]	11.2	2.1	.06	−.06	.01	−.02	−.2	1.5	.06	.07	−.09	.004
SE	18.1	8.2	.56	.12	.11	.02	.9	1.3	.14	.06	.05	.03
P	.54	.80	.91	.64	.95	.31	.87	.24	.66	.27	.07	.91
Orthogonal contrast 5: Roasted soybeans vs. roasted soybeans − urea with mixed diets												
Estimated difference[5]	−23.3	8.3	−.28	.08	.01	.004	.14	−2.6	−.26	−.14	.13	.01
SE	22.5	10.2	.69	.15	.13	.03	1.1	1.6	.17	.07	.06	.04
P	.30	.42	.68	.60	.97	.87	.90	.10	.15	.06	.04	.81

[1] Estimated difference = mean for alfalfa silage − mean for mixed silage.

[2] Estimated difference = mean for roasted soybeans − mean for soybean meal with alfalfa silage.

[3] Estimated difference = mean for distillers dried grains with solubles: corn gluten meal − soybean sources with mixed diets.

[4] Estimated difference = mean for roasted soybean meal and both roasted soybean diets − mean for solvent soybean meal with mixed diets.

[5] Estimated difference = mean for roasted soybeans with urea − mean for roasted soybeans with mixed diets.

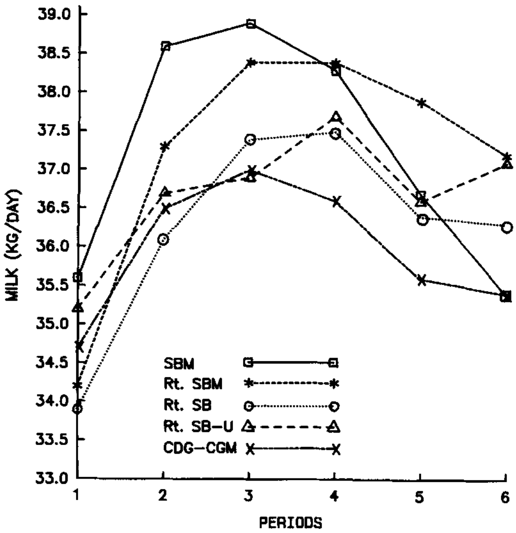

Figure 2. Adjusted means for milk production during six 10-d subperiods of the 60-d treatment period for mixed silage diets supplemented with soybean meal (□), roasted soybean meal (*), roasted soybeans (○), roasted soybeans + urea (△), and corn distillers grains – corn gluten meal (X) (Trial 2).

fed the A-SBM diet reached maximum production about 40 d into lactation. Cows on the A-Rt-SB diet were continuing to increase at d 70 of lactation. The increase in milk production with the A-Rt-SB may be attributed to the additional energy as well as the protected protein.

Cows consuming DDG-CGM diets had reduced protein production when compared to the soybean sources (Table 6, contrast 3). This agrees with the observations from trial 1 and those of Vandersall and Erdman (27). In both studies, milk production declined with feeding corn by-products compared with feeding soybean meal. The reduced milk protein secretion obtained with the corn by-products may have resulted from an inadequate supply of lysine to the mammary gland. The difference in milk production between the DDG-CGM and roasted soy products appeared to widen as time progressed (Figure 2).

The Rt-SBM, Rt-SB, and Rt-SB-U treatments depressed milk protein concentration compared with SBM; however, protein yields were not significantly different (Table 6, contrast 4). Roasting soybean meal or soybeans did not improve milk production with the mixed silage diets. Variable results have been obtained with heated soybean sources. Broderick (4), Sahlu et al. (20), and Schingoethe et al. (23) observed improved milk production, but others found no difference (5, 16) or decreased milk production (1) with heat-processed soybeans or soybean meal. Milk production and feed intake were similar with Rt-SBM and the RT-SB and Rt-SB-U treatments (contrast 5). The contrast data are not included here, but all probabilities were greater than .13, suggesting the addition of fat had no effect. This agrees with work by Mielke and Schingoethe (15); however, this group reported a depression of milk protein percent with the soybean treatments.

Fat-corrected milk and fat production were depressed with Rt-SB-U compared with Rt-SB treatment (Table 6, contrast 5). The estimated differences were −2.6 and −.14 kg/d for FCM and fat. Ammonia concentrations in the rumen may have actually been limiting at certain times with the Rt-SB-U treatment (7, 23). Ammonia concentrations, observed in a companion study with rumen cannulated cows fed the same diets, averaged over an 8-h period postfeeding were 11.8, 6.9, 6.0, 4.6, 6.2, 11.5, and 10.2 m*M* for SBM, Rt-SBM, Rt-SB, Rt-SB-U, DDG-CGM, A-SBM, and S-Rt-Sb, respectively. Even though the mean concentration of ammonia was adequate (4.6 m*M*) with the Rt-SB-U treatment, very low concentrations followed the high peak concentration at 1-h postfeeding.

Days open were averaged for each treatment; however, standard errors of means were greater than the differences between treatments (Table 7). Ferguson et al. (8) reported that probability of pregnancy was higher for cows older than 56 mo when fed distillers grain and soybean meal compared to soybean meal and whole soybeans. No differences were established for cows between 28 and 56 mo of age at calving in that study (8).

CONCLUSIONS

Feeding Ext SB, Rt-SBM, Rt-SB, or Rt-SB-U had little or no effect on milk production with corn silage or mixed silage diets, respectively. Cows fed the Ext-SB had greater milk fat production (.21 g/d) and depressed protein concentration (.21%) in Trial 1 when compared with protein concentration of the soybean meal diet.

TABLE 7. Average days open for cows on treatment diets in Trial 2.

	Treatments[1]						
	SBM	Rt-SBM	Rt-SB	Rt-SB-U	DDG-CGM	A-SBM	A-Rt-SB
Days open	106.9	122.5	106.1	125.0	102.1	105.3	131.7
SE	42.3	56.8	56.1	69.4	57.1	40.5	63.6
Observations	13	15	14	14	14	13	15

[1]Treatments with corn silage and alfalfa silage: SBM = solvent soybean meal., Rt-SBM = roasted soybean meal, Rt-SB = roasted soybeans, Rt-SB-U = roasted soybeans with urea, DDG-CGM = 59:41 distillers dried grains with solubles and corn gluten meal. Treatments with alfalfa silage: A-SBM = solvent soybean meal, A-Rt-SB = roasted soybeans.

The A-Rt-SB diets improved milk (2.0 kg/d) and fat production (.23 kg/d) in Trial 2. Milk and milk protein production were depressed with the DDG-CGM in Trial 1. In Trial 2, with mixed silage diets, milk production with DDG-CGM was similar to the soybean sources; however, milk protein production was depressed with the corn by-product supplement. Lysine supply to the mammary gland may have been limiting for milk protein synthesis. Ruminal annomia concentration may have been limiting for microbial synthesis with the DDG-CGM combination in Trial 1 or the lysine supply to the mammary gland may have been limiting when corn by-products were used to supplement corn-based diets. Milk production did not differ between SBM and the combination of corn by-products plus EB:CD supplement in Trial 1. Matching the protein supplement and the forage type according to protein degradation in the rumen and amino acid content may provide an efficient way to utilize protein. Resistant proteins may provide a more consistent increase in milk production with alfalfa silage than in feeding programs with 50% or more of the forage coming from corn silage.

ACKNOWLEDGMENTS

The authors are grateful to: Len Strozinski and staff for their care of the animals; to M. Dentine for her advice on the statistical analyses; to Steve Delonay and Kris Whitman for their help with the laboratory work; to the Gem Roaster Company for making a roaster available for the duration of the study; and to Triple "F", Inc., for supplying the extruded soy product. This research was funded in part by the American Soybean Association and the Distillers Feed Research Council.

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